



# **SiC Armor Tiles via Magnetic Compaction and Pressureless Sintering**

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# Successfully Processed High Density SiC using Dynamic Pressing and Pressureless Sintering

- High Green Densities
  - Lower Shrinkage- Net Shape
- Fine Microstructure
- Initial data suggests good material quality
- Three tiles pressed in <1 millisecond
  
- Ballistic tests still to be done

# Outline

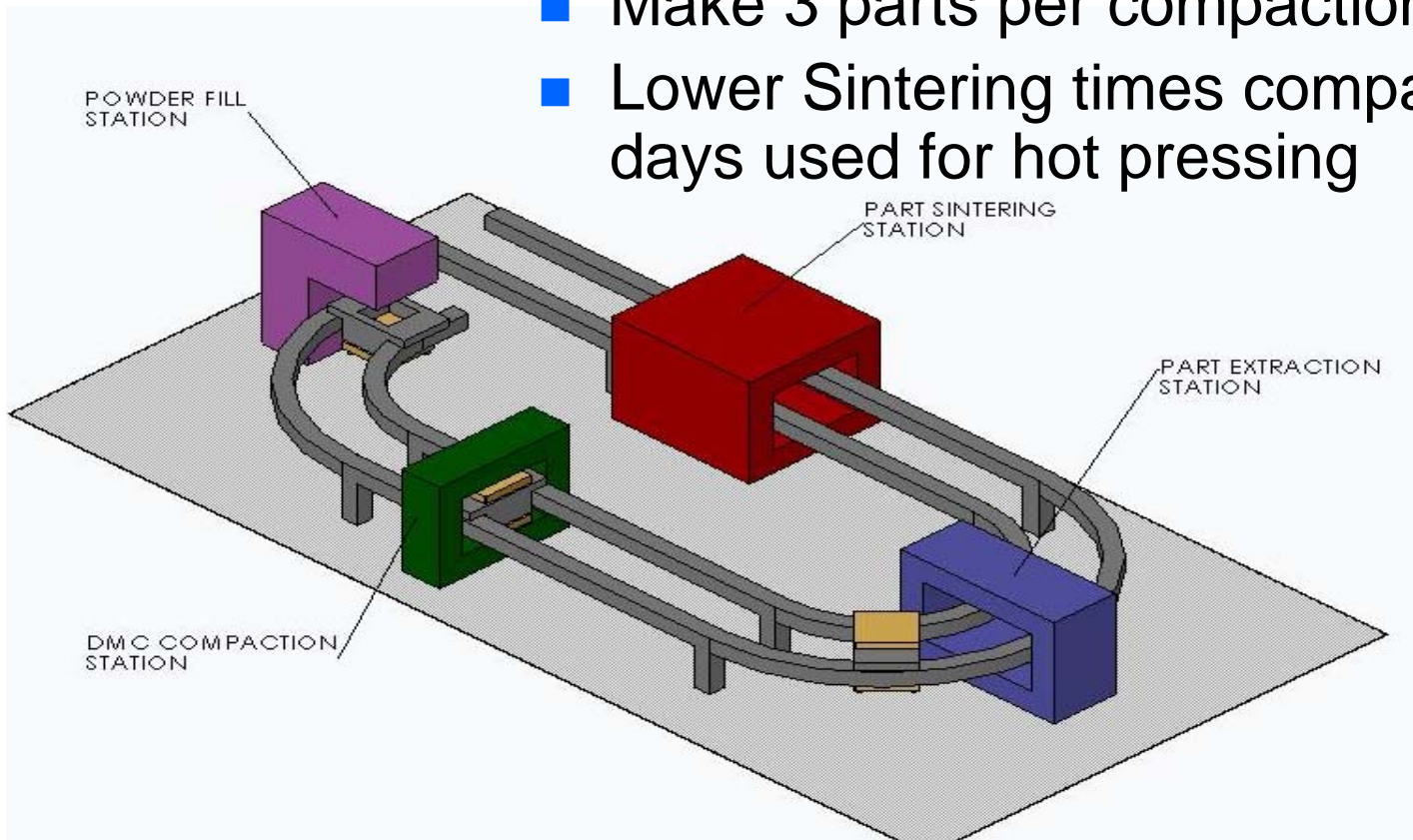
- Review Project Goals and Team
- What is the DMC process?
- Summary of work on sub-scale 1"x1"x1/2" and 1.25"x0.75"x0.75 "system
- Material optimization effort with DMC-PS process with 490 NDP (Superior Graphite) Powder
- Work in progress under SBIR Phase II effort

# Project Goals

- Designed and built a sub-scale DMC systems to produce a near net shape flat (1x1x1/2") and 1.25"x0.75"x0.75" armor tiles
- Pressureless Sinter (PS) SiC tiles to full density-on going
- Characterize test samples
- Populate 3'x3' Array for Ballistic test

# SiC Processing via Semi-Continuous Dynamic Magnetic Compaction

- DMC Compaction Time < 1 millisecond
- Make 3 parts per compaction cycle
- Lower Sintering times compared to days used for hot pressing



## Phase II Project Team

### Powders

- Superior Graphite powders (made for Pressureless sinter (PS) with B and C additives)
- Ceramatec (special powder chemistry for PS)

### Sintering

- MicroCeramics (not operational) and Ceramatec Inc

### Testing

- Ceramatec, ORNL ,ARMY and UDRI

# What is Dynamic Magnetic Compaction?

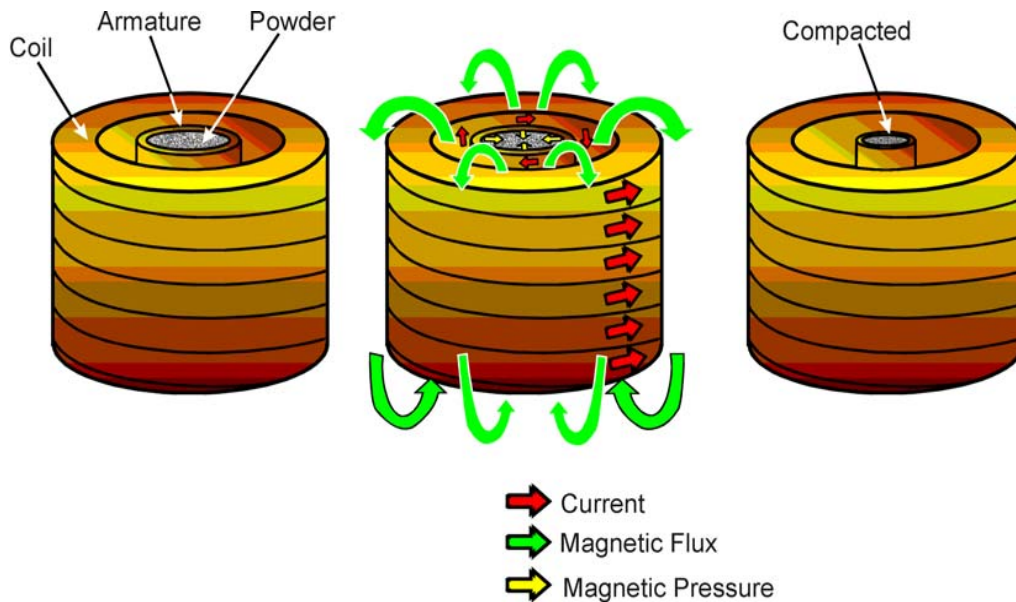
- Dynamic
  - Kinetic process
  - High compaction pressure for sub-millisecond
- Magnetic
  - Pulsed magnetics provide compaction energy
- Compaction
  - DMC delivers high density compacts
  - Fine microstructures





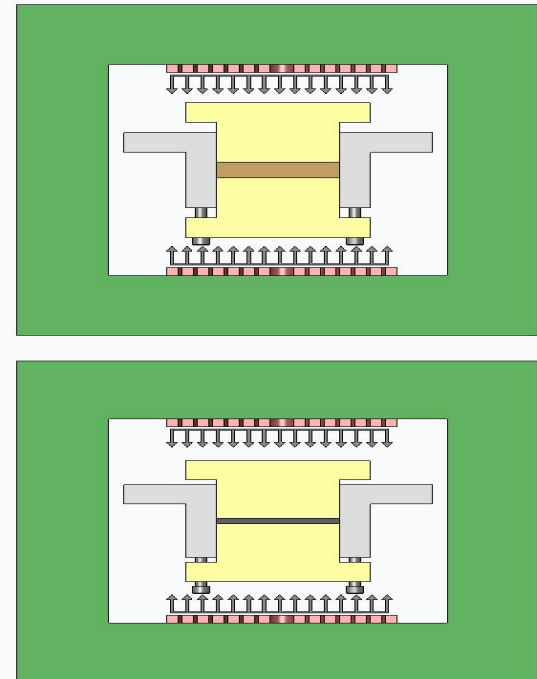
# Fundamentals of DMC Pressing

## Radial Compaction



- Net shaped cylindrical parts
- High L/D part shapes

## Axial Compaction



- Net shaped flat tiles



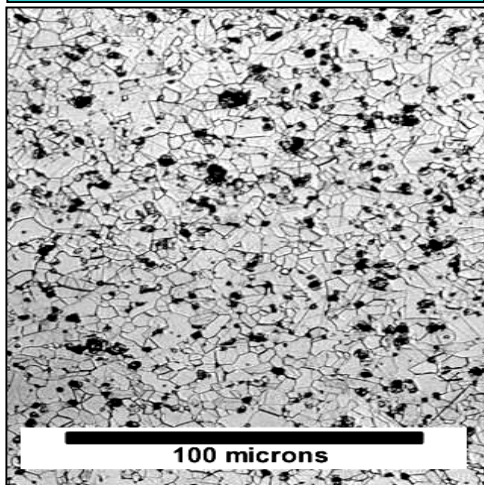
# **Sub-Scale Compaction System For 1''x1''x0.5'' and 1.25x0.75''x0.75'' SiC Tiles**

- ✓ FE Modeling
  - Magnetic Modeling
  - Dynamic Modeling
- ✓ Completed Final Design and  
Built Two Sub-Scale Flat Compactors
- ✓ Laboratory Testing of  
Flat Compactor in Progress
- Sample Fabrication and Process Optimization -  
In Progress

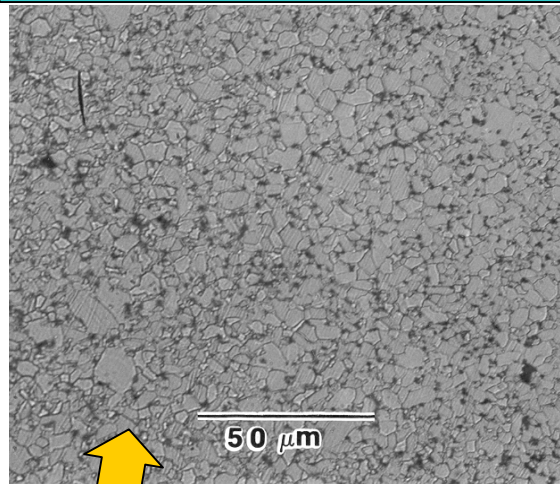
# Phase I Results Summary

## Microstructure of DMC/PS VS Conventionally Processed Samples

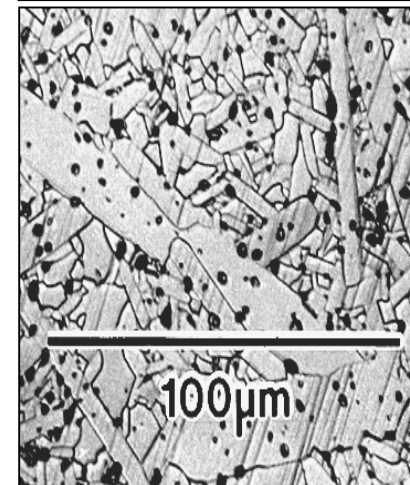
**Hot Pressed SiC**



**DMC & PS SiC**

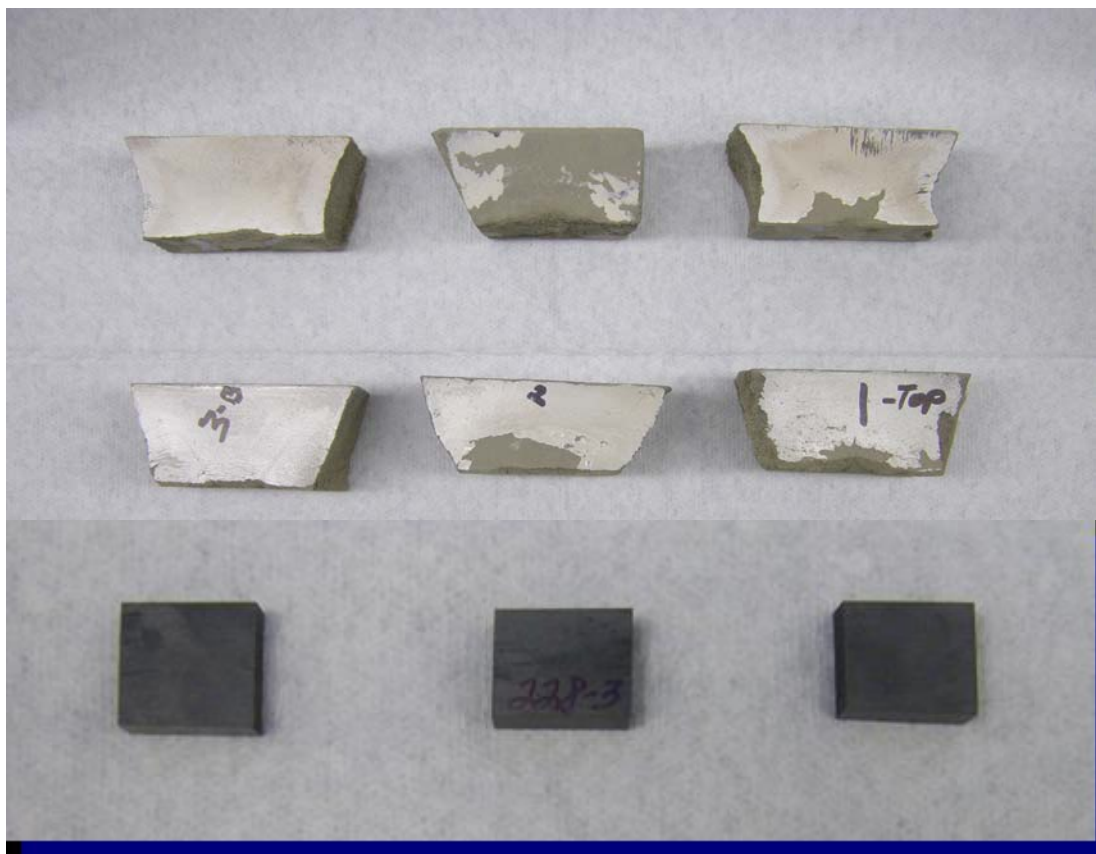


**PS-SiC**

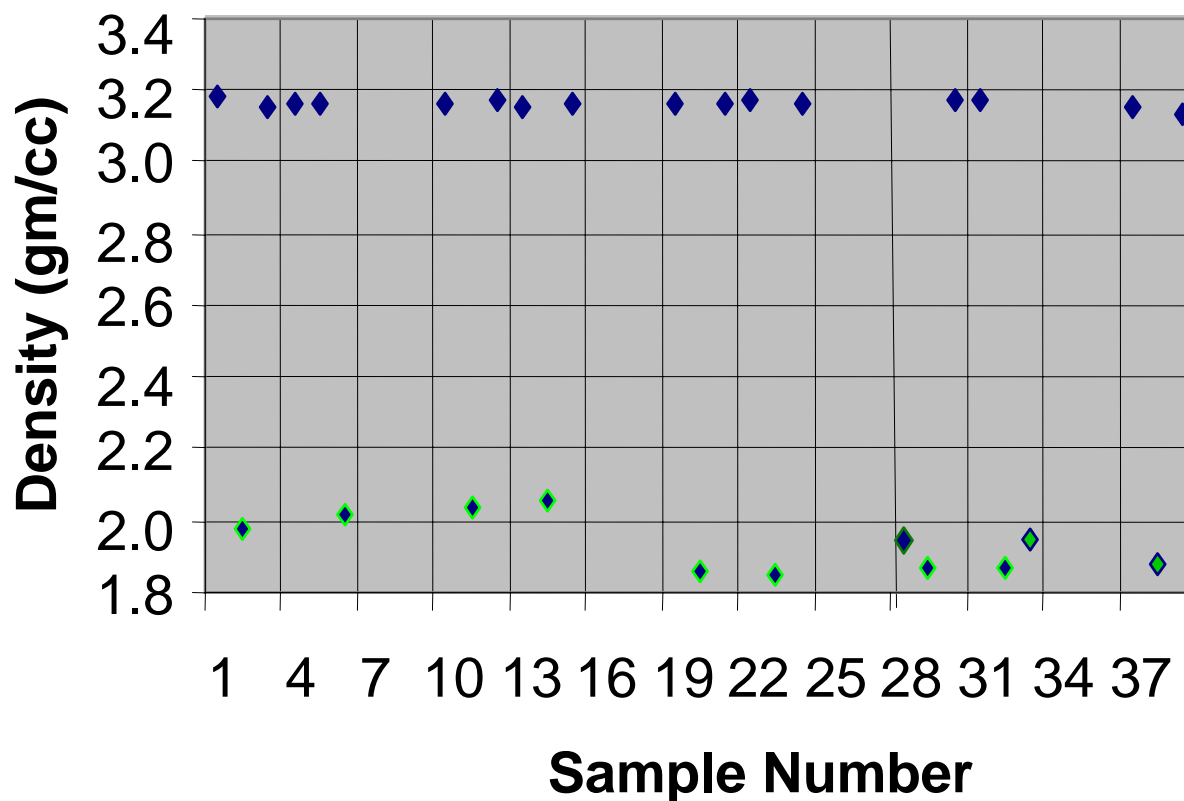


Uniform, Fine Grained Microstructure  
Minimal Grain Growth

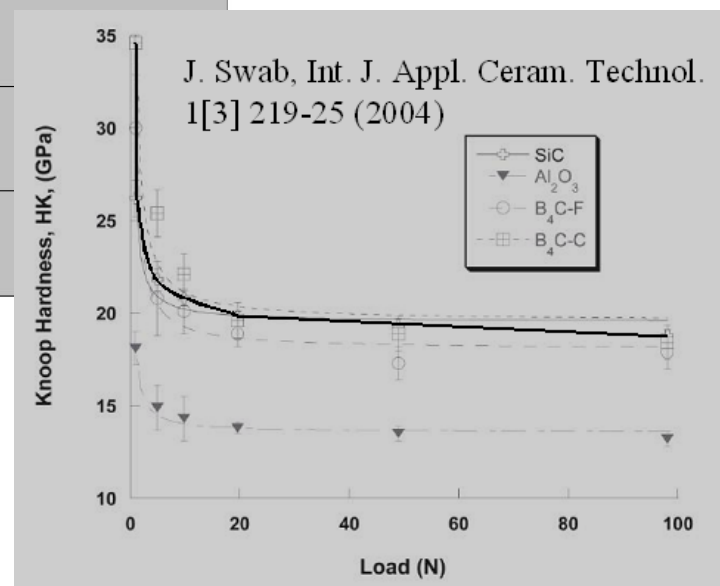
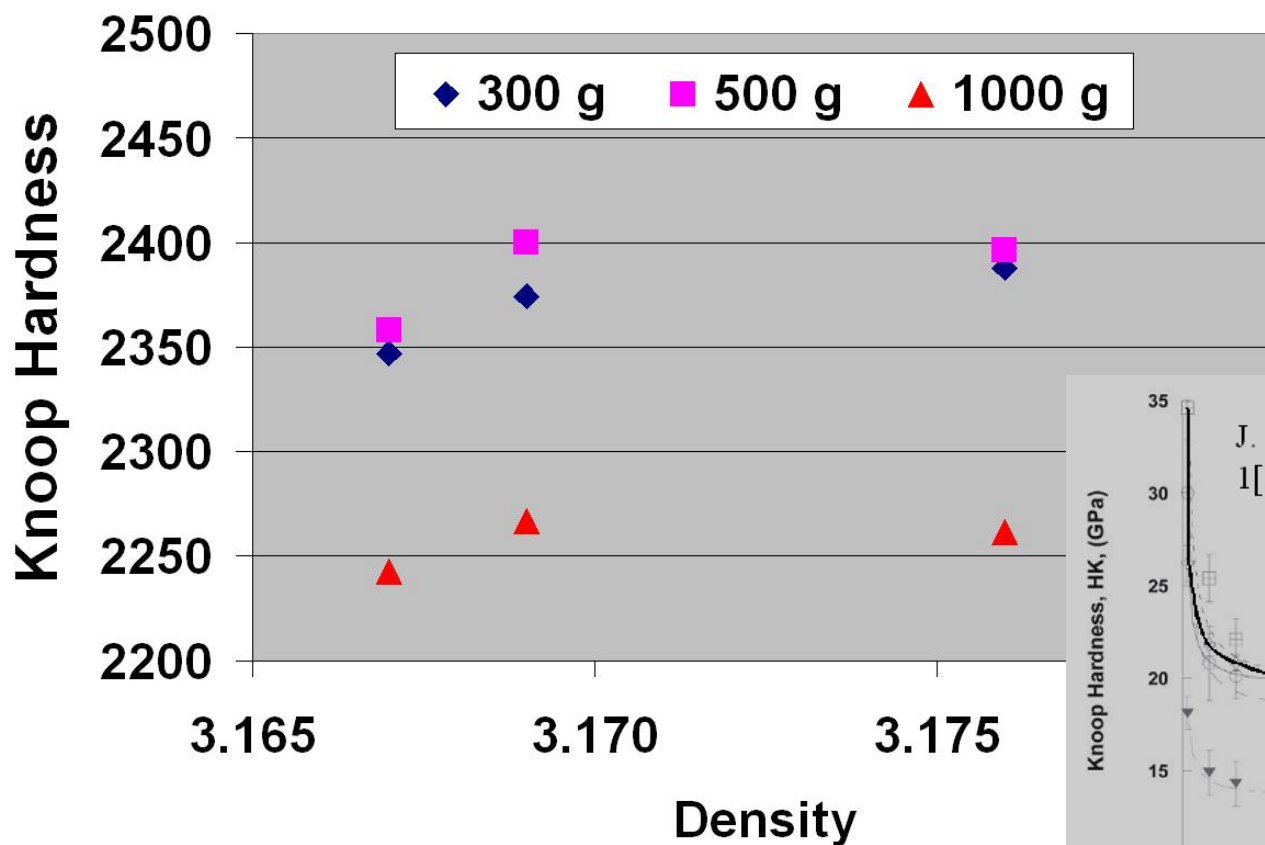
# Green and Sintered Samples



# Consistent Density in Each Batch and Batch to Batch

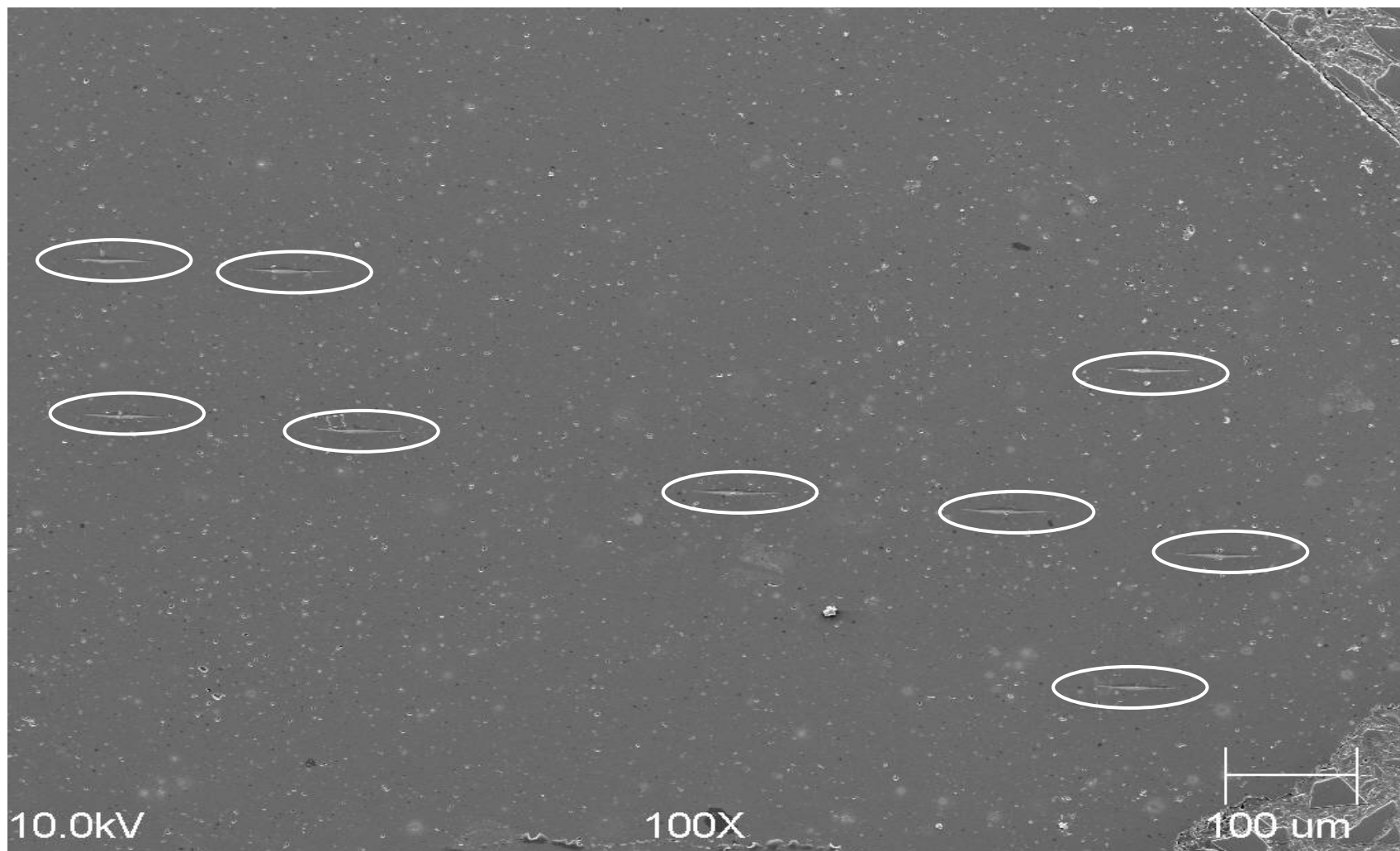


# Knoop Hardness

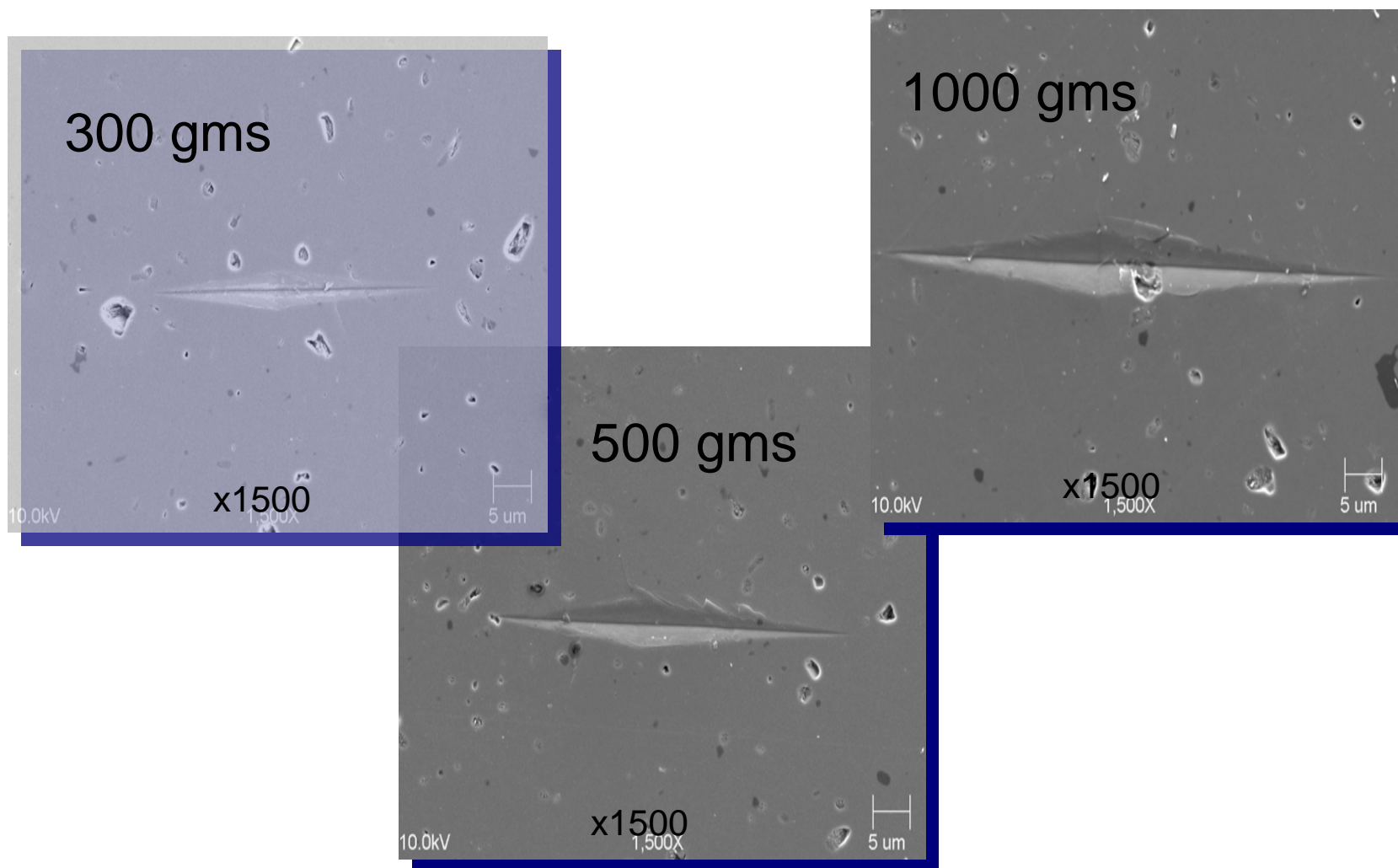




# Knoop Indentations



# Knoop Indentations at 300,500,1000gm load







## **\*Elastic Modulus Using Resonant Ultrasound Spectroscopy (RUS)**

<b>Material</b>	<b>Youngs Modulus-Gpa</b>	<b>Poisson ratio</b>
<b>(DMC&amp;PS) 98.4% Dense Phase I</b>	<b>430</b>	<b>0.19</b>
<b>DMC&amp;PS 99.2% Dense Current</b>	<b>437</b>	<b>0.16</b>
<b>Cercom (Hot Press)-SiC-N 100% Dense</b>	<b>460</b>	<b>0.16</b>



## Comparison of DMC and SiC-N

Property	Material (DMC & PS)	Hexalloy Direct sintered	SiC-N (Hot pressed)
Density (g/cc)	3.18	3.10	3.2
Knoop Hardness (GPa)	23.88 (Load 300gms)	28(Load 100gms)	24 (Load 300 gms)
Young's Modulus (GPa)	437	410	460
Poisson's ratio	0.16	0.14	0.16



# Future Work

- Density, Powder and Process Optimization
- Ballistic Testing
- Alternate Tile Shapes

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# P/M Applications – Power Train Gear

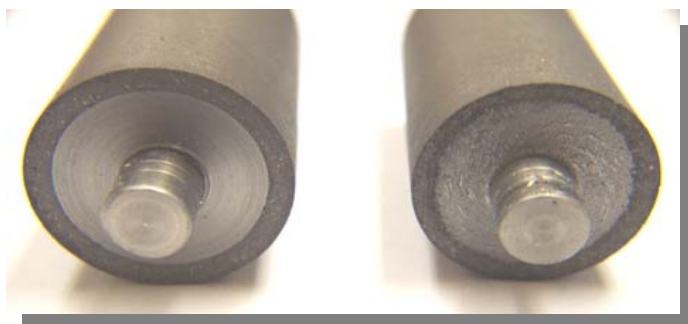


- Conventional process is machining forged blanks

# Motor Components via Co-Filling Powders



■ Stators



Solid Core   Powder Core

■ Rotors

